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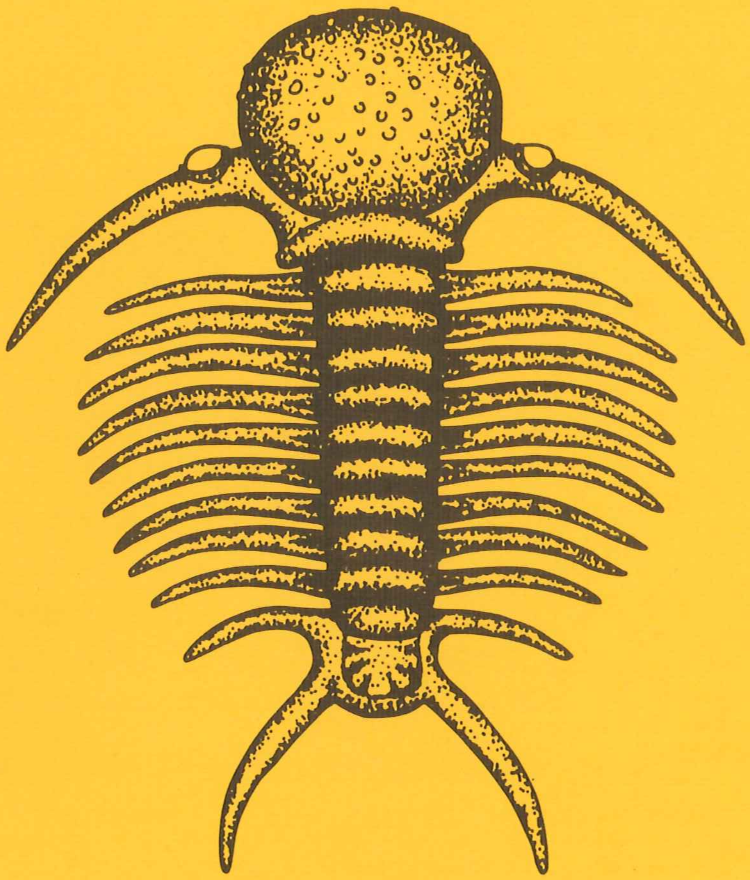

TRACE FOSSILS AND PALAEOENVIRONMENTS IN THE MIDDLE CAMBRIAN AT ÄLEKLINTA, ÖLAND, SWEDEN

BJÖRN GEDDA

LUND 1993 NR 49

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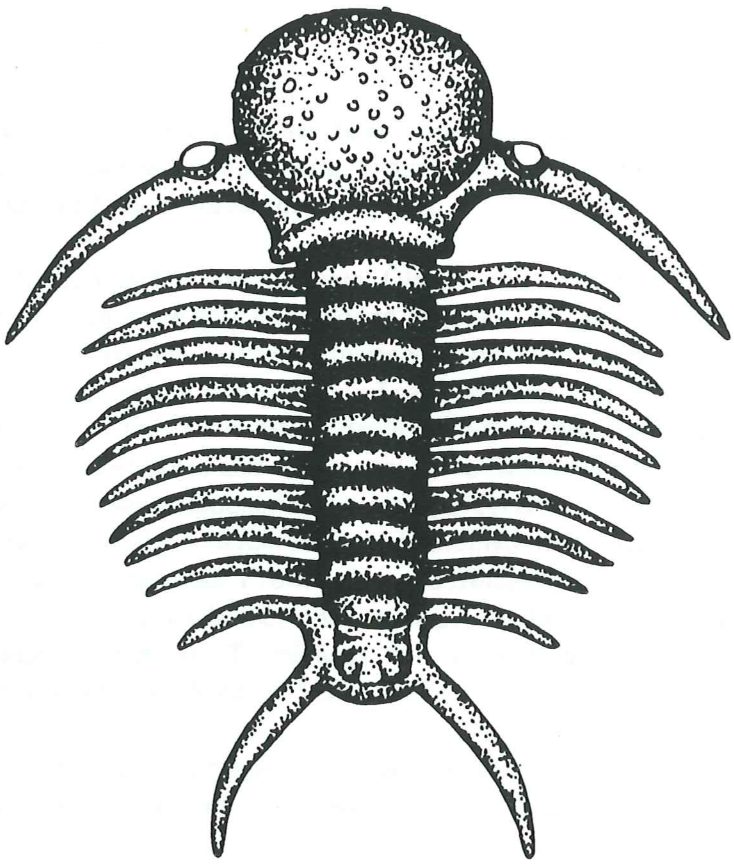

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The Middle Cambrian at Äleklinta, Öland, consists predominantly of a heterolitic sequence with interbedded shale and siltstone. The sediments were deposited in a westfacing marine bay by northeastern, sometimes reversing currents. Long periods of slow mud settling alternated with short periods of silt influx. Water depth was below wave base and stream-ripples, micro-ripples and occasional wave-ripples were formed. The contact to the superimposed stinkstone above is erosional. The ichnofauna is dominated by *Teichichnus* and *Planolites*. Other trace fossils are *Cruziana, Rusophycus, Protichnites* and *Halopoa*.□ *Trace fossils, silt, shale, micro-ripples,* kinneyans, *shrinkage cracks,* Cruziana, Halopoa, Planolites, Protichnites, Teichichnus, *Middle Cambrian, Äleklinta, Öland, Sweden, Rikets nät N 631715, W 195878.*

Björn Gedda, Avdelningen för historisk geologi och paleontologi, Geologiska Institutionen, Sölvegatan 13, S-223 62 Lund, Sweden.

Öland (Fig. 1 and 2), situated in the western part of the Baltic Sea, consists solely of sedimentary rocks of Cambrian-Ordovician age. The strata dip gently towards the east thus exposing the Cambrian layers in the western part of the island. Lower Cambrian sediments are only exposed in the area of Mörbylånga (Westergård 1929). The Middle Cambrian is better exposed and can be found throughout most of the western coast.

The Middle Cambrian on Öland is subdivided into three Stages, characterised in ascending order by the occurrence of *Eccaparadoxides oelandicus*, *Paradoxides paradoxissimus*, and *P. forchhammeri* (Westergård 1946, 1953). The *E. oelandicus* and *P. paradoxissimus* Stages are well developed and have a total thickness of 10 to 50 m. The *P. forchhammeri* Stage is usually present as a 0.1-0.4 m thick *Exporrecta* conglomerate. The *P. paradoxissimus* Stage is subdivided into four zones, of which only the second, the *Tomagnostus fissus* and *Ptychognostus atavus* Zone, is exposed at Älelinta. The ichnofossils at the Äleklinta sequence are exceptionally well preserved and numerous.

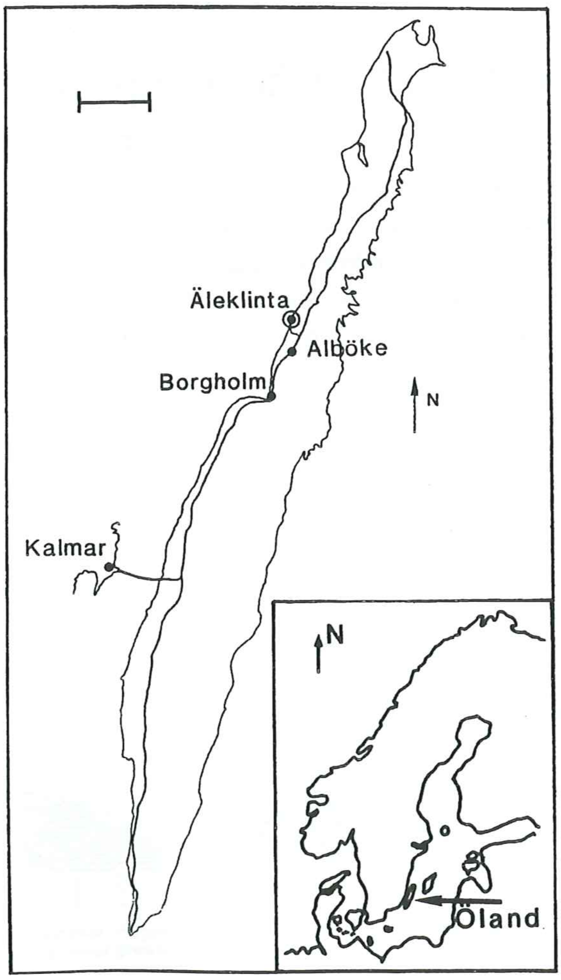

Fig. 1. The location of Öland and Äleklinta in the Baltic Basin. The scale bar is 10 km.

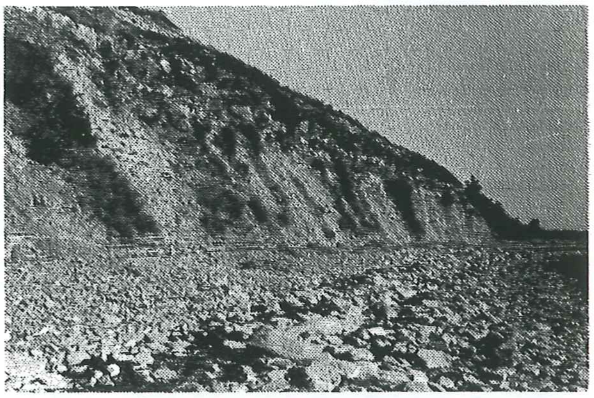
Fig. 2. The Äleklinta exposure.

In 1965, Martinsson published a major work concerning the Äleklinta sequence, treating morphological aspects of the trace fossils and sedimentary structures. The present paper deals with the sedimentological and environmental aspects, and presents some complementary trace fossil data.

Methods and material

The sampling was performed along a vertical section at continuous intervals. Ripple structures, ripple dimensions and current directions were analysed. All herein treated ichnotaxa are identified according to Häntszchel (1975), with the ethological classification (Fig. 3) according to Müller (1962) and the toponomic classification (Fig. 4) according to Martinsson (1970). All samples are stored at the Geological Institution, Lund. Thin sections of two siltbeds, approximately 1 m apart, were analysed. X-ray diffraction analyses were performed on samples of an unconsolidated clay at 47 cm below the zero level, and on a shale 30 cm below the zero

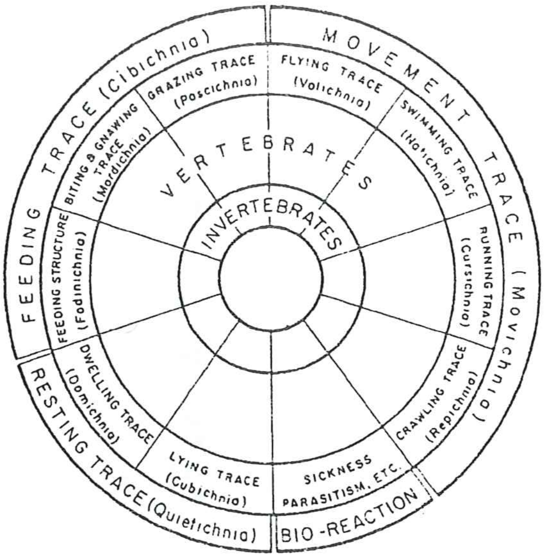

Fig. 3. Ethologic classification of trace fossils according to Müller (1962).

level. Both samples were oriented and treated according to Hardy & Tucker (1988). The samples were disaggregated using the freezing method (Hardy & Tucker 1988).

Description of the Äleklinta sequence

The sequence (Fig. 5) exposes approximately 5.6 m of the *Paradoxissimus* beds. The lithology consists of shale, sometimes with minor amounts of silt, and well sorted thin-bedded siltstone beds (1-15 cm thick). The matrix

Fig. 6. Close-up of the sedimentary sequence at Äleklinta. Picture taken at 3 m below the reference level. The scale-bar is 10 cm.

consists of calcium carbonate. Glauconite and pyrite is also present. The X-ray diffraction analyses showed that both the shale and the clay (at 47 cm below the zero level) contain chlorite and illite.

The *Paradoxides paradoxissimus* Stage comprises 1.7 m flaser bedded heterolites, 0.4 m lenticularly bedded heterolites and 3.5 m of wavy bedded heterolites (Fig. 6). This is followed by the *Exporrecta* conglomerate and the Upper Cambrian *Agnostus pisiformis*-bearing stinkstones and alum shale, and the Lower Ordovician limestones (Tjernvik 1956).

The bases of the silt horizons of the heterolites are typically marked by sedimentary structures created by the current that deposited the subsequent silt layer. The traction marks usually appear as furrow casts and prodmarks, but deeper washouts are also present. The latter are about 10 cm wide, 5 cm deep and at least 50 cm long, and indicate swift streams. The average ripple is 5 cm long and has an amplitude of 0.3 cm. It must be emphasised, however, that the

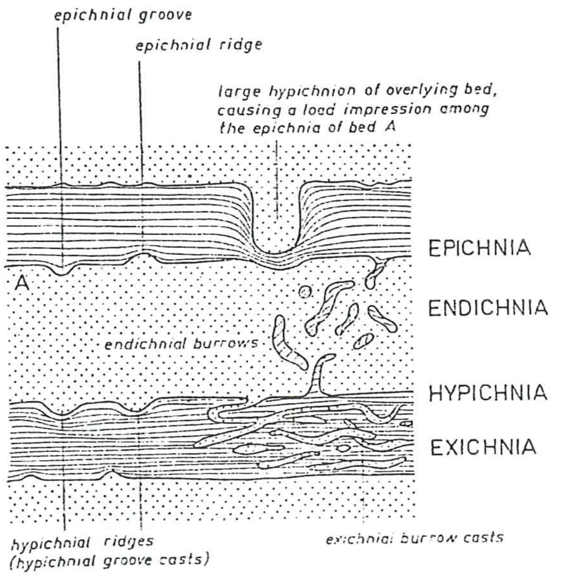

Fig. 4. Toponomic classification of trace fossils according to Martinsson (1970).

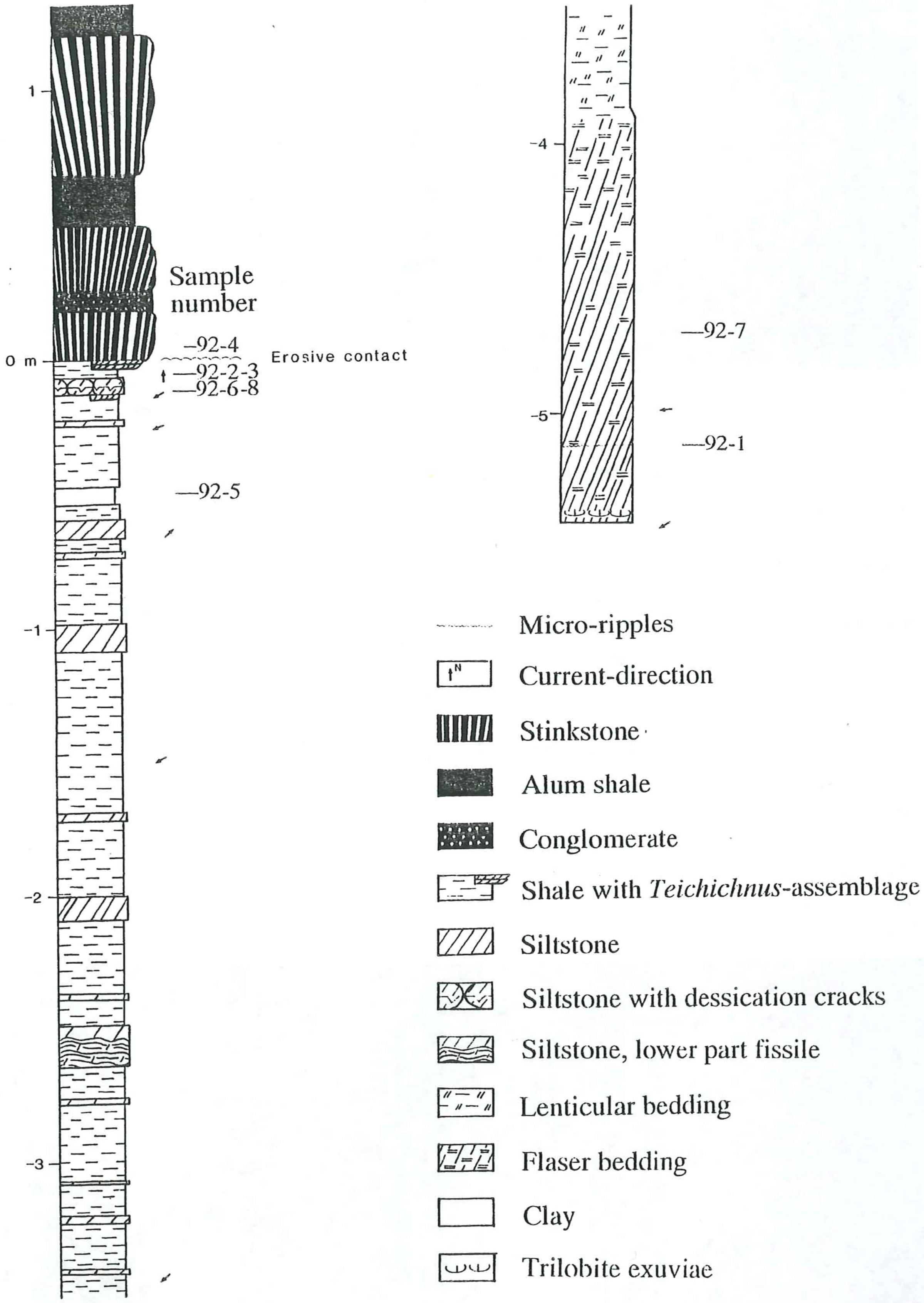

Fig. 5. Measured section at Äleklinta, showing general lithologic succesion and sedimentary structures.

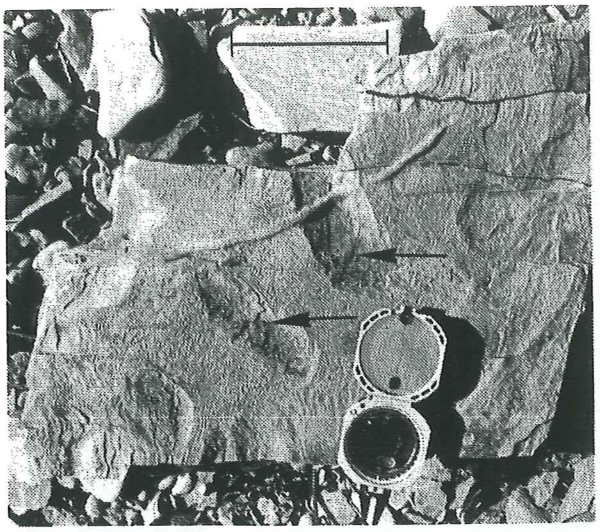

Fig. 7. Micro-ripples, macro-ripples (arrows) and a *Halopoa* sp. that has been produced from right to left in the picture. The scale-bar is 10 cm, sample number 92-1.

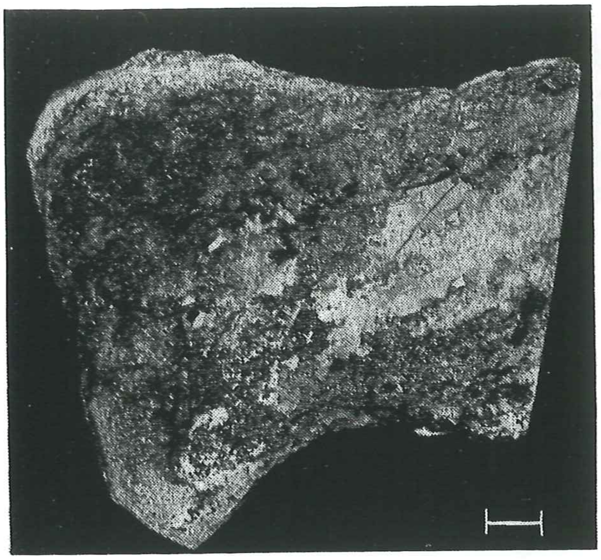

Fig. 9. Nodule containing shrinkage cracks. The scale-bar is 1 cm, sample number 92-2.

ripples might have suffered some compaction. Most ripples are typical current ripples but wave ripples and micro-ripples are also present (Figs 7 and 8).

Micro-ripples

Micro-ripples (Fig. 8) were found in two beds in the lower part of the sequence (Fig. 5). The uppermost part of each bed consists of a silt layer only a few millimetres thick without internal structures. The upper suface is undulating and does not seem to have been deposited by the same sedimentary regime as the underlying macro-ripples. The micro-ripples are typically draped by shale. All micro-ripple crests are oriented parallel to the sediment transport direction of the underlying macro-ripples.

Shrinkage cracks

Shrinkage cracks occur in an about 3 cm thick nodular silty layer 5 cm below the zero level (Figs 9 and 10). The nodules consist, in ascending order, of a pyrite-bearing siltstone with slump or float structures, a muddy layer with calcium carbonate-filled cracks, and a layer of recrystallized limestone (Fig. 11).

Fossil contents

Body fossils in the *Paradoxides paradoxissimus* siltstone and shale are rarely complete and mostly sparse, except for a bed in the lower part of the sequence where *Paradoxides* fragments are abundant. Few other body fossils have been found, although Westergård (1950) reported

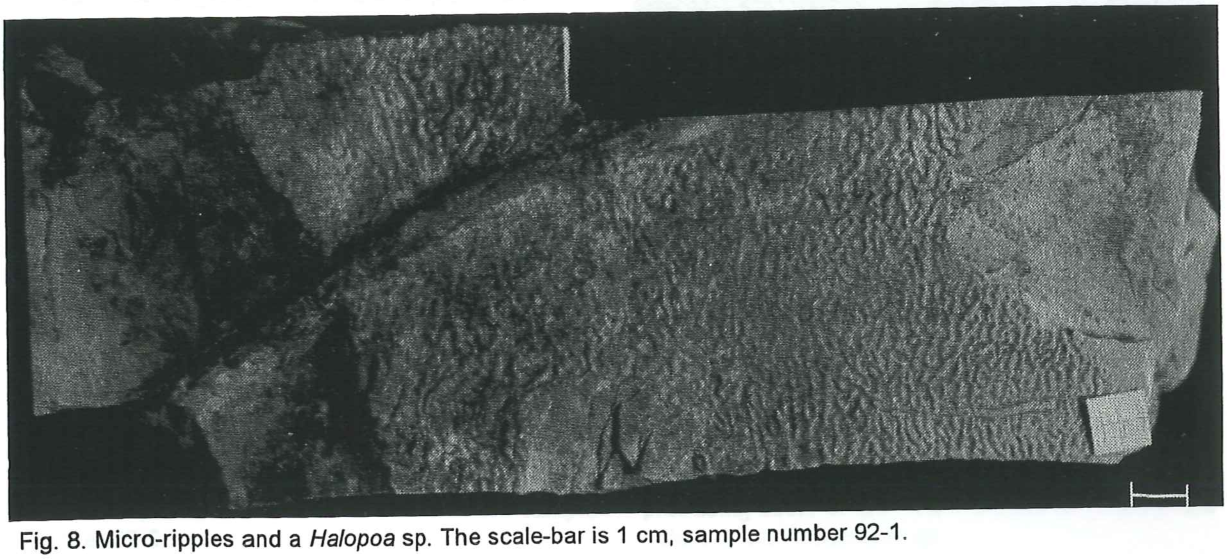

Fig. 8. Micro-ripples and a *Halopoa* sp. The scale-bar is 1 cm, sample number 92-1.

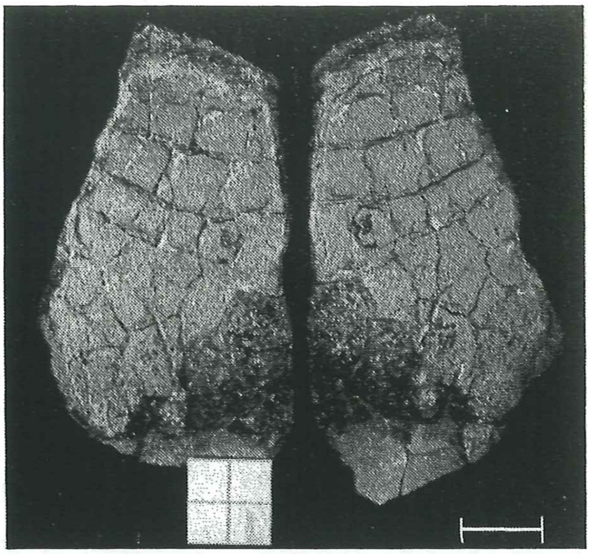

Fig. 10. Nodule split up to show cracks. The scale-bar is 1 cm, sample number 92-3.

Ellipsocephalus lejostracus, and Martinsson (1965, p. 183) reported small phosphatic brachiopods. Trace fossils are abundant throughout the sequence, mostly as exichnia and hypichnial grooves, but also as endichnia. The traces are well preserved and the compaction of the sediment is moderate. No major diagenetic changes have taken place. Six ichnotaxa are described herein.

Teichichnus sp.

Series of stacked tubular burrows (Figs 12 and 13) vertical to bedding with pipe at top. The length of the entire trace is up to 135 cm (Martinsson 1965), height about 10 cm, and width of tube approximately 2 cm. The shape is straight or slightly sinuous and generally not

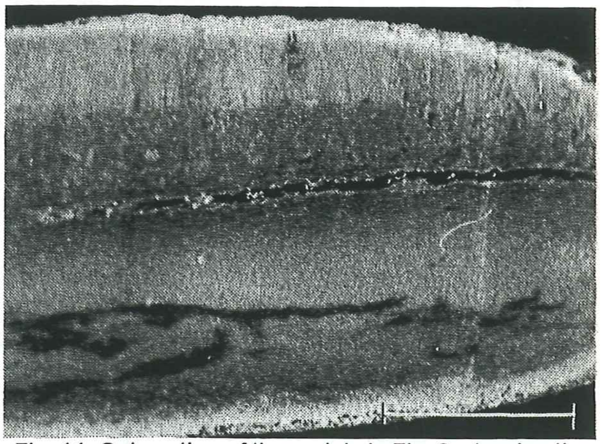

Fig. 11. Cut section of the nodule in Fig. 9, showing the internal stratification. The scale-bar is 1 cm, sample number 92-2.

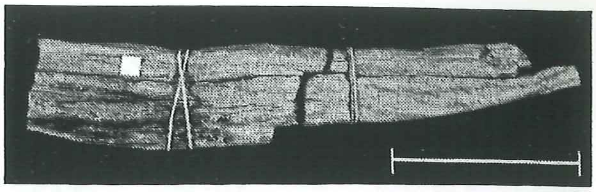

Fig. 12. *Teichichnus* sp. The scale-bar is 10 cm, sample number 92-4.

branching. They are exichnia and the producer has had a fodinichnial behaviour. The producer is unknown, but the tubes often have a bilobed bottom which suggests that the trace-makers where arthropods, although other metameric animal groups cannot be excluded (Häntzschel 1975). The trace-maker could have migrated upwards as well as downwards (Kennedy 1975, p. 380). *Teichichnus* sp. is present throughout the sequence, and close to the contact with the stinkstone they dominate the sediment. The uppermost traces are in contact with the stinkstone.

Halopoa sp.

Long, slightly curved to straight trails are dug along the bed surface (Figs 7 and 8). Surface of

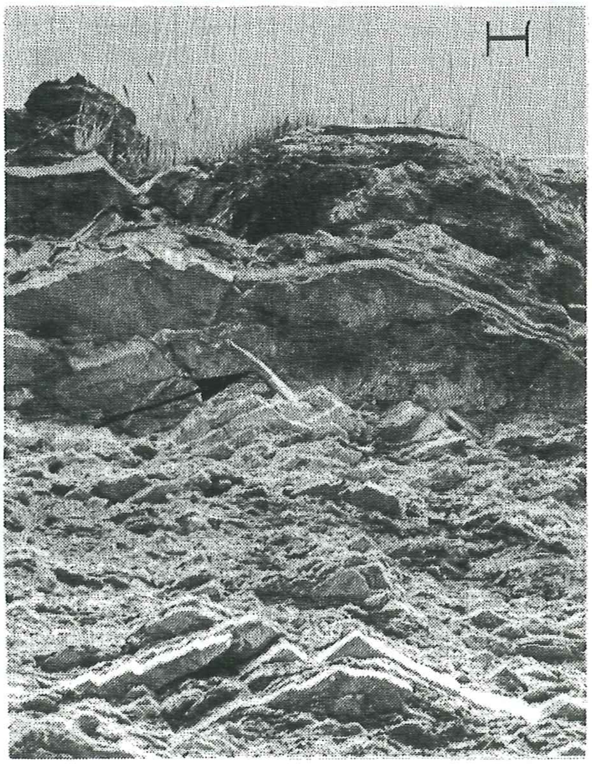

Fig. 13. The *Teichichnus* sp. are more persistent to erosion than the rest of the sediment. The picture shows a *Teichichnus* sp. close to the contact to the stinkstone, protruding about 40 cm. The scale-bar is 10 cm at the height of the *Teichichnus* sp.

the trails are imbricate or lycopodiaceous. The diameter is approximately 5-10 mm. The producers was a epichnia with a repichnial behaviour. They were probably episamonts (Häntzschel 1975). *Halopoa* sp. is very common along the top-surface of the silt beds. Martinsson (1965) grouped the *Halopoa* with the *Gyrochorda*.

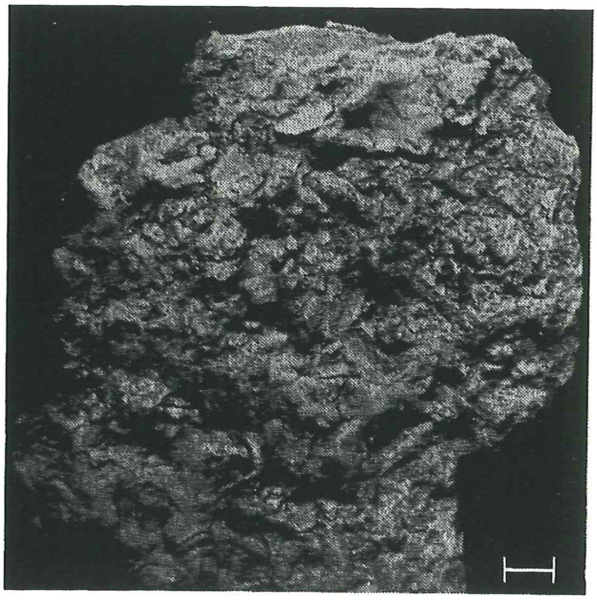

Fig. 14. *Planolites* sp. The scale-bar is 1 cm, sample number 92-5.

Planolites sp.

The traces (Fig. 14) are 2-4 mm in diameter, originally cylindrical but now slightly compressed. They are sinuous to almost straight, often leaving bedding plane. *Planolites* sp. seldom or never branch and intersections are rare. The traces were made by a backfilling deposit feeder and occurs in the shale and the siltstone. They are exichnial to endichnial and were made by an animal with repichnial behaviour typical for infauna.

Rusophycus sp.

The only trace found of this ichnotaxon (Fig. 15) is 15 mm long and 20 mm wide hypichnia. The producer had cubichnic or foodichnic behaviour.

Ichnospecies incerta No. 1

The only trace found of this ichnotaxon (Fig. 16) is 20 mm long and 10 mm wide double

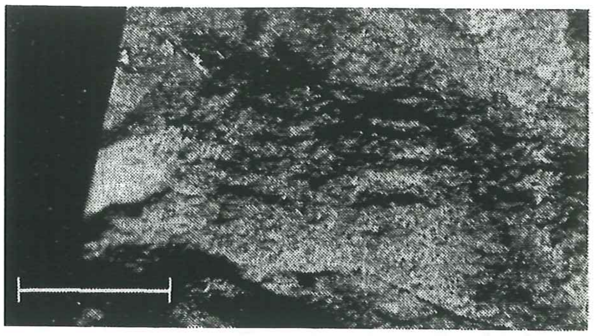

Fig. 15. *Rusophycus* sp. The scale-bar is 1 cm, sample number 92-6.

hypichnial drag trail. The trace indicates repichnial and/or fodinichnial behaviour and was probably made by the pygidium or limbs of a swimming or drifting trilobite.

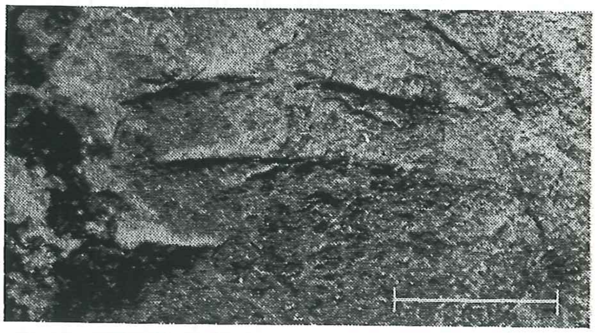

Fig. 16. Ichnospecies incerta 1. The scale-bar is 1 cm, sample number 92-7.

Ichnospecies incerta No. 2

One burrow, 20 mm wide, 140 mm long (Fig. 17) was found. It is epichnial to exichnial, and the producers behaviour was repichnic or fodinichnic. The animal has penetrated the mudlayer, down to the silt, and then returned upwards again.

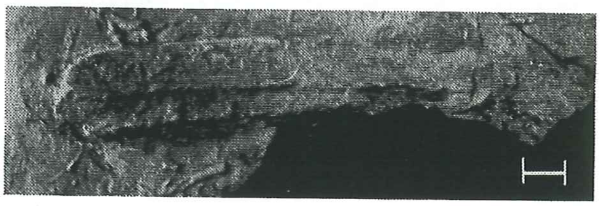

Fig. 17. Ichnospecies incerta 2. Direction of movement probably leftward. The scale-bar is 1 cm, sample number 92-8.

Discussion

Most preserved traces correspond to mud-dwellers, and are found either as silt-filled tubes in the shale or as casts in the siltstone. The siltstone beds are rarely bioturbated except for in their upper- and lowermost millimeters. The rarity of escape structures indicates what a devastating effect a thin silt layer can have on mud-dwelling life forms. Benthic life forms were virtually obliterated from the site, leaving a barren silt surface where mostly non-digging benthos could survive. As a new mudlayer was deposited, the recolonising animals settled from the uncovered surrounding areas. The animals were digging in a fairly well oxygenated sediment, usually in the uppermost 10-20 centimeters. The substrate comprise sand and mud rarely reached by wave activity.

The sedimentary record described (Fig. 5) indicates that mud was deposited in a marine embayment during long calm periods. Occasionally the bottom was covered by sudden silt-influxes. The silt was deposited by south-westernly directed currents which sometimes turned in a reversed direction. It is not clear if these reverse currents appeared with any periodicity. Deposition took place on the shelf below the fair weather wave base. The light colour of the shale and siltstone, and the abundant benthos give the impression of an environment with high nutrient- and oxygen levels. Pyrite nodules (sizes up to several centimeters) and glauconite observed in thin sections indicate changes towards anoxic and reducing conditions within the sediments, below the upper nutrient- and oxygen-rich levels.

The undisturbed interior of the silt beds indicates that each silt influx lasted for such a short period of time that major colonisation of the siltgrounds rarely occurred. These quick silt influxes covered several km^2 (Martinsson 1965) and must have been devastating for the benthic life. Since very few escape structures are found, it is logical to assume that recolonisation was made from unaffected surrounding areas.

The shrinkage cracks with the calcareous layer, and the multitude of *Teichichnus* at the top of the sequence indicate drastic environmen-tal change which affected both the sediment and the benthic fauna. A temporary higher degree of calcium carbonate or salt in the water column could have caused the pore water in the top mud-layer to escape and induce cracking (Collinson & Thompson 1982, p. 140). The cut-off *Teichichnus* at the top of the sequence indicate erosion. The abundant *Teichichnus* could imply a lowered competitive level, and maybe the disappearance of an important predator.

It is possible that the calcareous layer, and the multitude of *Teichichnus,* are the effects of a precursor to the regression that formed the *Exporrecta* conglomerate. Häntzschel (1975) describes *Teichichnus* as an endichnial trace, while all examples in this investigation are exichnial.

The micro-ripples were considered by Martinsson (1965) to be kinneyans. Walcott (1914, p. 107) defines kinneyans as algal structures in calcareous material, built up of thin, subparallel layers separated by narrow intervals that are not much greater than the thickness of the layers forming the body. In this paper though, the structure is not considered to be kinneyans since Walcott´s (1914) description does not agree with the almost two-dimensional top layer that forms the micro-ripples at Äleklinta. Martinsson (1965) also noted a similarity to micro-ripples made up by settling organic detritus, which he had seen in the Baltic Sea during calm weather, and he referred to them as oscillation ripples. A more liable explanation is that the micro-ripples are wrinkling structures. According to this interpretation the shale has shrunk (because of dehydration), or has been moved (because of a stream traction pushing it), thus causing the wrinkling pattern.

The *Halopoa* (Figs 7 and 8) was probably dug after the last silt layer had been laid down but before there was any mud deposition. Important to note is that although the trail raises 5 mm above the bedding surface, the sediment below the trail is only disturbed to a depth of 1 or 2 mm. It is questionable how the necessary concentration of silt has been achieved. Martinsson (1965) grouped the *Halopoa* with the *Gyrochorda*, although the absence of a typical plaitelike structure in the *Halopoa* (Häntzschel 1975) is enough to question their relationship.

The *Planolites* (Fig. 14) has been dug by a backfilling deposit feeder (Häntzschel 1975), which lived both in silt and mud and crossed the boundary between the substrates without difficulty. *Planolites* are very common as silt filled tubes in the shale. Tubes in siltstone are more rare. It is not clear whether all found planolitoid traces belong to *Planolites*, but they are regarded as such, because of their similar appearance.

The *Rusophycus* (Fig. 15) has a cubichnic character that has been created by a trilobite digging in the uppermost mud layer. Since no epichnial traces occur, one can assume that the trilobites dwelled in the mud.

The Ichnospecies incerta No. 1 (Fig. 16) has similarities with *Protichnites* in that it could be a part of the repichnia, and only the pygidium and two or three limbs have touched the bottom. The trace is similar to *Diplichnites* in that it could be a drag trail, made by a current-transported animal. It is probable that it corresponds to *Diplichnites*.

Since the Ichnospecies incerta No. 2 (Fig. 17) have no apparent striae, the direction of movement cannot be determined. The rounded ends to the left in Fig. 17, and some very faint striae, give the impression of a rightward *Cruziana*-movement, but that does not explain how the silt got pushed up into the mud. The simplest and most probable explanation lies in a rightward motion of the trace producer. The backfill did not give a lasting impression as long as the animal dug through the mud. When the animal reached the silt, the silt that was probed backwards caused a lasting cast. When the animal left the silt to the right the trace again was filled with mud without giving a lasting impression. The trace could also be the lowermost part of a *Teichichnus*. The upper parts would then have been filled with mud, thus not giving a lasting impression. The vertical thinning of the trace to the right, and the bimorphous shape that is typical of well preserved *Teichichnus*, supports this theory.

Acknowledgements

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References

Collinson, J. D., Thompson, D. B., 1982: *Sedimentary structures*, 1-194. George Allen and Unwin..

Hardy, R. & Tucker, M., 1988: *X-ray powder diffraction.. In* Tucker, M., Techniques in sedimentology, 198-228. Blackwell Scientific Publications.

Häntzschel, W., 1975: *Trace Fossils and Problematica. Part W, 1-269. In* C. Teichert (ed) Treatise on Invertebrate Paleontology. Geological Society of America and University of Kansas Press.

Kennedy. J. W., 1975: *Trace Fossils in Carbonate Rocks. 377-398 In*: W. Frey (ed.) The Study of Trace Fossils, Springer Verlag.

Martinsson, A., 1965: Aspects of a Middle Cambrian thanatotope on Öland. *Geologiska Föreningens i Stockholm Förhandlingar 87*, 181-230.

Martinsson, A., 1970: Toponomy of trace fossils. *In* T. P. Crimes and J. C. Harper (eds.) Trace fossils. *Geological Journal, special issue 3*, 323-330.

Müller, A. H., 1962: Zur Ichnologie, Taxiologie und Ökologie fossiler Tiere. *Freiberger Forschungshefte C 151*, 5-49.

Tjernvik, T. E., 1956: On the Early Ordovician of Sweden - stratigraphy and fauna. *Bulletin of the Geological Institution of the University of Uppsala 36.* 107-284.

Walcott, C. D., 1914: Cambrian geology and palaeontology. III. Pre-Cambrian Algonkian algal flora. *Smithsonian Miscellaneous Collections 64*, 77-156.

Westergård, A. H., 1929: A deep boring through Middle and Lower Cambrian strata at Borgholm. *Sveriges Geologiska UndersÜkning C 355*, 1-19.

Westergård, A. H., 1946: Agnostidea of the Middle Cambrian of Sweden. *Sveriges Geologiska Undersökning C 477*, 1-140.

Westergård, A. H., 1950: Non-agnostidean trilobites of the Middle Cambrian of Sweden. II. *Sveriges Geologiska Undersökning* C 511, 1-57.

Westergård, A. H., 1953: Non-agnostidean trilobites of the Middle Cambrian of Sweden. III. *Sveriges Geologiska Undersökning C 526*, 1-59.

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